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GLYCEMIC INDEX AND GLYCEMIC LOAD AS RELATED TO CITRUS

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Abstract. **In some parts of the world, glycemic index (GI) is now widely recognized as a reliable, physiological based classification of foods according to their postprandial (after meal) glycemic effect (a measure of the change in blood glucose following ingestion of carbohydrate containing foods). Carbohydrates have been classified as simple or complex (sugar, starch and fiber) based on their degree of polymerization. However, their effects on health may be better described on the basis of their physiological effects which depends both on the type of constituent sugars and the physical form of the carbohydrate. The level of postprandial glycemia, however, is dictated both by the quality and the quantity of carbohydrate. To consider both factors simultaneously, the concept of glycemic load (GL) was introduced. GL is defined as the product of the carbohydrate content per serving of food and its GI. The purpose of this presentation is to introduce the concepts of glycemic index, glycemic load and the citrus data currently available related to these two concepts. New GI/GL data developed from authentic commercially processed Florida orange juices will be presented.**

Glycemic Index (GI) was introduced in the early 1980s by Jenkins and co-workers, and later proposed by Jenkins et al. (1985) as a possible tool for the management of type 1 diabetes[a] and disorders of lipoprotein metabolism (dyslipidemia).

The initial intent of glycemic index values was to prescribe a varied diet of low glycemic index foods for diabetics. GI has been endorsed by many official health agencies around the world, as a method to classify carbohydrate rich foods. In recent years, the uses of GI and Glycemic Load (GL) have been expanded to include being perceived as a key player for the prevention of diseases and obesity.

"Although the use of low GI foods may reduce postprandial hyperglycemia, there is not sufficient evidence of long-term benefit to recommend use of low GI diet as a primary strategy in food/meal planning" (Franz et al., 2002).

In 1997, a joint committee of the Food and Agriculture Organization (FAO) and the World Health Organization (WHO), reviewed the available research evidence regarding the importance of carbohydrates in human nutrition and health. That committee endorsed the use of GI method for classifying carbohydrate rich foods, and recommended that the GI values of foods be used in conjunction with information about food composition to guide food choices (FAO/WHO, 1997).

Simply GI is the measure of the change in blood glucose following the ingestion of carbohydrates containing foods. GI addresses the quality of carbohydrates, but not the effect of the quantity of carbohydrates in a food portion on glycemia. The glucose and insulin responses depend on both the quantity and quality of the carbohydrates. Salmeron et al. (1997) introduced the term glycemic load to improve the reliability of predicting the glycemic response of a given diet. The GL of a food is its amount of carbohydrate in a serving multiplied by its glycemic index. One concern with GL is that it is a mathematical concept, and has not been physiologically validated as a reliable measure of glycemic response (Ludwig, 2003).

Florida Department of Citrus' economic research department has shown that the advent and popularity of the Atkins' and South Beach diets have had a negative effect on citrus juices sales. Both of these diets are low carbohydrate diets and suggest the use of GI as a guideline for meal planning, focusing on the use of low GI foods. The South Beach Diet specifically excludes citrus juices as part of its diet plan (Agatston, 2003).

This report on GI and GL is aimed to address the issue of citrus juices in the context of its suitability as part of any healthy diet. Citrus juices are one of the most readily available, high nutrient dense, no-fat foods, and are listed as a low category GI food (Foster-Powell et al., 2002; Brand-Miller et al., 1996).

Definitions

Glycemic Index. Glycemic index is defined as the incremental area under the blood glucose response curve of a 50g carbohydrate portion of a test food expressed as a percent of response to the same amount of carbohydrate from a reference food (white bread or glucose) taken by the same subject over a specified period of time (Jenkins et al., 1981). It compares equal quantities of carbohydrates and provides a measure of carbohydrate quality but not quantity (Foster-Powell et al., 2002).

Carbohydrates. Carbohydrates are an important part of a healthy diet because they provide fuel for the body. They are found in foods in a variety of forms. The most common and abundant ones are sugars, fibers, and starches.

Carbohydrates have been classified as simple or complex based on their degree of polymerization. Simple carbohydrates included monosaccharides, such as fructose and glucose, and disaccharides, such as sucrose, lactose and maltose. Fig. 1 shows the chemical structure of the monosaccharides fructose and glucose.

Complex carbohydrates include everything made of three or more linked monosaccharides, with various degrees of cross-linking, like starches and fibers.

Starch is composed of a mixture of two substances: amylase, an essentially linear polysaccharide, and amylopectin, a highly branched polysaccharide.

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[a]Type 1 diabetes or insulin dependent diabetes mellitus, IDDM, is the result of the absolute deficiency of insulin as a consequence of β-cell loss or damage—while in type 2 diabetes or non-insulin dependent diabetes mellitus, NIDDM, insulin is secreted, sometimes in greater than normal amounts, but is a relative deficiency of insulin due to increased tissue resistance to insulin action. Usually begins in middle aged or older people. However, it is seen in a few young persons (Stubbs, 1983).

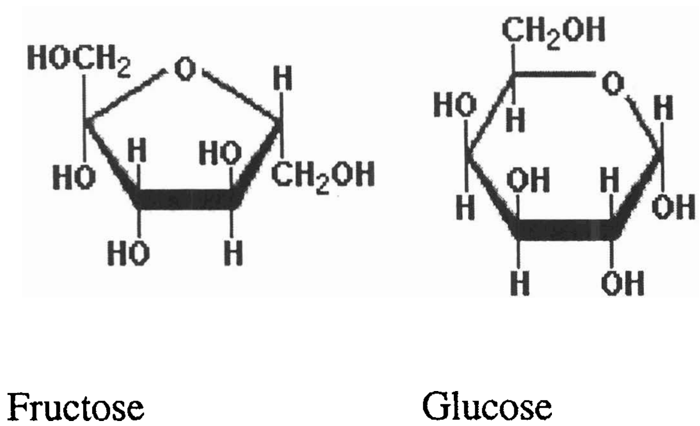

Fig. 1. Chemical Structure of Monosaccharides.

Many polysaccharides, unlike sugars, are insoluble in water. Dietary fiber includes polysaccharides and oligosaccharides that are resistant to digestion and absorption in the human small intestine, but are completely or partially fermented by microorganisms in the large intestine.

Fiber is an exception, because its molecule is structured in such a manner that humans cannot break it down into monosaccharides. Thus it passes through the body mostly undigested. They can be categorized by their source of origin or by how easily they dissolve in water. Soluble fibers with few or no ramifications, can be partially dissolved in water. Insoluble fibers are highly ramified and do not dissolve in water. Approximately 75% of the total fiber in an orange is insoluble fiber. In grapefruit approximately 50% of the fiber is insoluble.

Glycemic index and its implications. In order to quantify the variation in rates of absorption of carbohydrates into the blood stream, and their postprandial glucose responses, Jenkins et al. (1981) developed the GI and calculated the relative glycemic effects of carbohydrate exchanges for 51 foods.

Foster-Powell and Miller (1995) published the first international table of GI values. In 2002, the table was revised, and the International Table of Glycemic Index and Glycemic Load Values was published. The table was compiled from both published and unpublished data from verified sources, and contains nearly 1300 entries representing over 750 different foods tested using standard methods (Foster-Powell et al., 2002).

Brand-Miller et al. (1996) set the following values for low, medium and high GI foods, using glucose as the reference food: Low GI = 55 or less, Medium GI = 56-69 and, High GI = 70 or more.

The 2002 International Table of Glycemic Index and Glycemic Load Values, list the average GI value for orange juice as 52, and grapefruit juice as 48. According to Brand-Miller et al. (1996), orange juice and grapefruit juice would be classified as low GI value foods.

The 2005 Dietary Guidelines for Americans, published by the U.S. Department of Health and Human Services (USHHS), states that carbohydrates are part of a healthful diet. The acceptable macronutrient distribution ranges (AMDR[b]) for carbohydrates is 45 to 65% of total caloric intake. In a 2,000 calorie diet, 900 to 1,300 calories could be provided by carbohydrates. Carbohydrates can be naturally present in foods or be added to them during processing and preparation. Although the body response to them is the same, it should be emphasized that naturally containing sugar foods, such as fruit and vegetables are source of many nutrients. Therefore, they can promote health and reduce chronic disease risk. The 2005 Dietary Guidelines states that the inclusion of orange juice can help meet the recommended levels of potassium intake. An 8 oz. glass of orange juice (unsweetened) provides only 105 to 112 calories and significant amounts of vitamins and minerals (Gebhardt and Thomas, 2002).

Glycemic index methodology. A typical determination of the GI value for a food includes feeding volunteers a portion of food that contains 50 g of available carbohydrates, and then measuring the effect on their blood glucose levels over the next two hours for each person. The area under the curve (AUC) of their two-hour blood glucose response for this food is measured. On another occasion, the same participants consume an equal-carbohydrate portion of glucose (reference food) and their two-hour glucose response is also measured. A GI value for the test food is then calculated for each participant, by dividing their AUC for the test food by the AUC for the reference food. The final GI value for the test food is the average GI value for the total number of participants. An example for the two-hour blood sugar response for glucose (reference food) and lentils is shown in Fig. 2.

Some laboratories use white bread as the reference food for measuring GI values while others use glucose. If glucose is used, its GI value is 100 and the GI value for white bread is 70. If white bread is used as the reference food, its GI value is 100 and that of glucose is 137 (Foster-Powell et al., 2002).

The use of different reference foods leads to conflicting published values for GI. In addition, 50 g of carbohydrates in white bread is more difficult to determine accurately than is 50 g of glucose (Pi-Sunyer, 2002). Differences in testing methods include the use of different types of blood sampling methods: capillary versus venous. Although capillary and venous

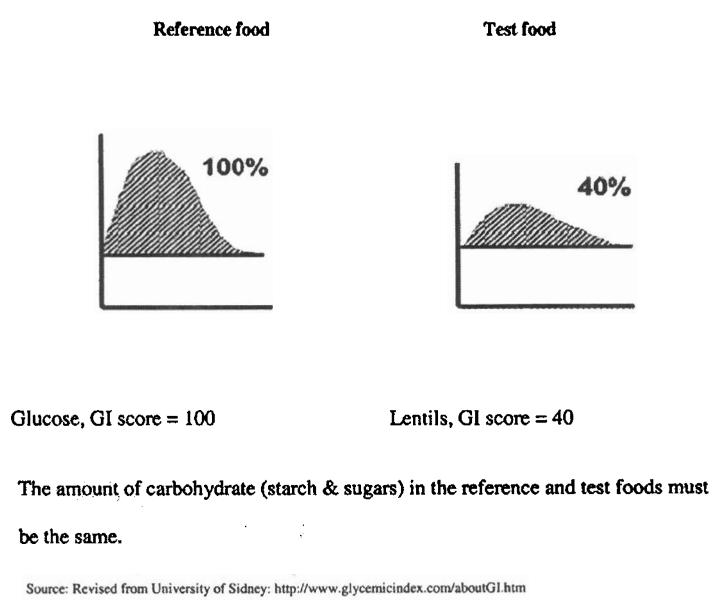

Fig. 2. The two hour blood sugar response of glucose and lentils.

[b]Acceptable Macronutrient Distribution Ranges (AMDR): Range of intake for a particular energy source that is associated with reduced risk of chronic disease while providing intakes of essential nutrients. If an individual consumes in excess of the AMDR, there is a potential of increasing the risk of chronic diseases and/or insufficient intakes of essential nutrients.

blood glucose values have been shown to be highly correlated, it appears that capillary blood samples may be a more relevant indicator for reliable GI testing. After the consumption of a food, glucose concentrations change to a greater degree in capillary blood samples than in venous blood samples. Therefore, capillary blood samples may be a more relevant indicator of the physiological consequences of high GI foods. Other factors that can lead to differences in GI values include different experimental time periods, and a variety of serving sizes (Foster-Powell et al., 2002).

Glycemic Load. Salmeron et al. (1997) introduced the concept of Glycemic Load to quantify the overall glycemic effect of a portion of food. The GL of a typical serving of food is the product of the amount of available carbohydrate in the serving, and the GI of the food. The higher the GL, the greater the expected elevation in blood glucose and insulin response to the food.

There is some controversy concerning the value of GL data. In many cases, GL is not based on a normal or typical amount of food or drink ingested, therefore, GL does not provide realistic information, unless the food is weighed prior to consuming it. The value of GL is that it provides an understanding of the relationship between specific amount of food and its glycemic response.

The Glycemic Load values can be applied to mixed meals or whole diets by calculating the weighted GL value of the meal or diet. Table 1 offers an example of a breakfast meal containing bread, cereal, sucrose, milk and orange juice. The individual food's GI values are based on glucose = 100.

Using this type of calculation, there is a good correlation between meal GL and the observed glycemic responses of meals of equal nutrient composition.

Brand-Miller et al. (2003) states the following range of values for low, medium and high GL values for individual foods as follows: Low GL = 10 or less, Medium GL = 11-19 and High GL = 20 or more. A typical diet has approximately 100 GL units per day (range 60-180).

The 2002 International Table of Glycemic Index and Glycemic Load Values lists the average GL values for orange juice as 12-13 and grapefruit juice as 9-11. These values place orange juice as a medium GL value food and grapefruit juice as a low/medium GL value food respectively. None of the juices tested were classified as 100% juice from Florida.

Though endorsed by many official health agencies around the world as a method to classify carbohydrate rich foods, the principles underlying GI and GL have not, to our knowledge, been recognized by any governmental or professional entity in the United States.

The amount, type (glucose versus fructose), and rate of digestion of dietary carbohydrate are the primary determinants of postprandial glucose and insulin responses. Fructose produces much lower glucose and insulin responses than glucose, because it is slowly converted to glucose in the liver and only some of this glucose is released into the circulation (Wolever, 2000).

It is recognized that higher intakes of free sugars threaten the nutrient quality of diets by providing significant energy without specific nutrients. The 2005 Dietary Guidelines recommends that it is important to choose carbohydrates wisely.

The understanding of the meanings of glycemic index, glycemic load, and glycemic load of a meal (the sum of the GL contribution of individual foods making up a meal) can be confusing to the average consumer. To make matters worse, the glycemic index of a food can be determined by various methods (time over which standard blood glucose is measured, how blood samples are withdrawn, etc.), using various reference foods (glucose or white bread) and the health status of the subjects. It would be beneficial if a single standardized methodology were agreed upon by all organizations endorsing the use of glycemic index.

Due to the absence of specific information on the glycemic index and glycemic load of Florida orange juices, the Department of Citrus contracted with Glycemic Solutions (St. Petersburg, Fla.), a professional clinical research organization, to determine the GI and GL of three commercially available 100% Florida orange juices. The juices evaluated were a premium not from concentrate juice, a premium not from concentrate with high pulp juice and a from concentrate juice.

The glycemic index was determined *in vivo* utilizing the Glycemic Solutions standardized clinical protocol. Ten Non-Diabetic Human subjects were used for each product tested. White Bread was used as the standard. Each subject was fed a minimum of three bread standards for comparison to the product tested. Both a 4oz and an 8oz sample of each juice were evaluated to determine the GI and GL's associated with different levels of intake. Calculations were made using the area under the curve as compared to bread standards (converted to the glucose scale). The GL's for each of the three juices tested was calculated as previous describe in the paper. The results of the tests on the three juices appear in Table 2.

Among the foods providing carbohydrates, orange juice is a nutrient dense, fat-free food that provides for maintenance of good nutrition. There is no scientific based evidence to exclude citrus juice as part of any healthy diet including most popular low-carbohydrate diets.

Table 1. Glycemic index and glycemic load of a meal.

Food	Grams Glycemic Carbohydrate	Proportion of total Glycemic Carbohydrate	Food Glycemic Index	Meal Glycemic Load[z]
Bread	25	0.298	70	20.9
Cereal	25	0.298	50	14.9
Milk	6	0.071	27	1.9
Sucrose	5	0.060	61	3.6
Orange juice	23	0.274	52	14.2
Total	84			55.5

Source: Modified from FAO/WHO, 1997.
[z]Values for GL of each food equals the proportion of total glycemic carbohydrate multiplied by the food GI. The sum of these values is the meal GL.

Table 2. Glycemic Index/Glycemic Load results.

OJ	GI	GL	CHO
NFC—4 oz.	33	4.3	—
NFC—8 oz.	48	12.5	26.1 g
NFC-high pulp—4 oz.	34	4.5	—
NFC-high pulp—8 oz.	47	12.5	26.7 g
From Concentrate—4 oz.	27	3.6	—
From Concentrate—8 oz.	48	12.9	26.9 g

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